ployed. In contrast to this it is interesting to note, as Adler (*l. c.*) emphasizes, that the right angle (square) is a much more powerful instrument. Indeed Plato's instrument for the solution of the problem of the duplication of a cube[1] is equivalent to the use of two right angles to solve a binomial cubic equation. So also four right angles could be used to solve a fifth degree binomial. Descartes employed a similar instrument with right angles[2] for the insertion of several geometric means between two line segments.

The fundamental ideas here introduced were adapted by Lill[3] so as to extend to the solution of polynomial equations with numerical coefficients. From this Adler readily formulated, in particular, the result: Problems of the third and fourth degree can be rigorously solved geometrically by means of several right angles.

COLLEGIATE MATHEMATICS FOR WAR SERVICE.

SEND WAR SERVICE COMMUNICATIONS TO DR. HENRY BLUMBERG, University of Illinois.

FIRING DATA.

By J. K. WHITTEMORE.

In the first part of this paper, I shall outline a course in "Firing Data," and in the second part, make some suggestions as to the conduct of such a course. The outline is based on the course given in the last college year in the Yale R. O. T. C. The course in firing data includes all the mathematics necessary for an officer of the Field Artillery, and is an extremely important part of the training for a commission in that service. The work, as here described, applies to the U. S. 3-inch gun, the British 18 pounder, and the French 75 mm., but the tables used in the examples apply only to the U. S. 3″ gun; they are given in Danford and Moretti's "Notes on Training Field Artillery Details," Yale University Press, Sixth Printing, Feb., 1918.

The fundamental firing data problem is the computation of data for the battery for the opening salvo in indirect laying from observations made at the battery commander's station. These data are range, site, deflection and deflection difference. Indirect laying is pointing a gun at a target invisible at the gun; both target and battery must be visible at the battery commander's station.

The course begins with certain definitions which must be thoroughly learned

[1] M. Cantor, *Vorlesungen über Geschichte der Mathematik*, 3. Auflage, Band I, Leipzig, 1907, pp. 227, 353. *Cf. L'Algèbre d'Omar Alkhayyâmî* publiée . . . par F. Woepeke, Paris, MDCCLI, pp. 94–96; A. Conti, in *Fragen der Elementargeometrie* (Enriques), Band 2, p. 215; and A. Adler, *l. c.*, 1906, p. 237.

[2] *La Géometrie*, livre II, *Oeuvres de Descartes* publiées par C. Adam et P. Tannery, Vol. 6, Paris, 1902, p. 391.

[3] E. Lill, (1) Résolution graphique des équations numériques de tous les degrés à une seule inconnue, et description d'un instrument inventé dans ce but," *Nouvelles annales de mathématiques*, 1867, (2), tome 6, pp. 359–362; (2) "Résolution graphique des équations numériques d'un degré quelconque à une inconnue," *Comptes rendus de l'académie des sciences*, Paris, tome 65, pp. 854–857. See also T. Vahlen, *Konstruktionen und Approximationen in systematischer Darstellung*, Leipzig, 1911, p. 141.

by the student. These are given alphabetically in Drill Regulations for Field Artillery and in Danford and Moretti. This arrangement is convenient for reference, but the definitions should be grouped in proper connection for instruction. For the comprehension of this paper it is necessary to give the following:

Mil, a unit of angular measure, is one sixteen hundredth of a right angle, and is approximately one thousandth of a radian. The numerical measure of an angle in mils exceeds one thousand times its radian measure by about two per cent. The usefulness of the mil depends on the formula for small angles, $m = c/k$, where m is the angle in mils subtended by a line c units long at a distance of 1,000 k units. If c is the side of a right triangle opposite the small angle m mils, and 1,000 k the adjacent side, then m is given by the formula with an error not greater than two per cent. if m is not greater than 330. The formula is exact for a certain value of m nearly equal to 270. The same formula is used for small m when 1,000 k is not the leg but the hypothenuse of the right triangle. In this case the value of m given by the formula is always too small, the error varying from two per cent. at zero to about three per cent. for $m = 300$.

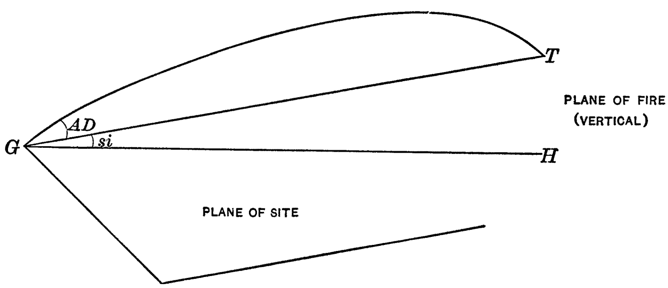

Fig. 1.

Plane of site is the plane containing the line GT and the horizontal line perpendicular to the axis of the bore of the directing gun. G is the muzzle of the directing gun for which the data are computed, and T, the target. (Fig. 1.)

Site (si) is the angle in mils of the plane of site with the horizontal plane. It is positive or negative according as T is above or below G. To avoid the use of negative numbers we use SI, where $SI = 300 + si$. The term site is used for other elevations; thus we speak of the site of the target at the battery commander's (BC) station. (Figs. 1 and 2.)

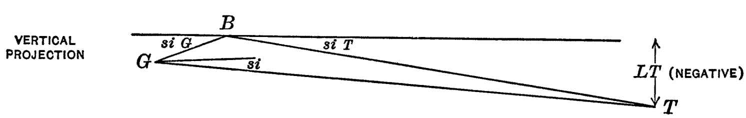

Fig. 2.

Angle of departure (AD) is the angle in mils of the tangent to the trajectory of the projectile at the point of departure from the gun with the plane of site. (Fig. 1.) For most service conditions in the Field Artillery the trajectory may

be regarded as rigid without important error, so that change of site produces no change in the relation of range and AD. Actually the elevation of the gun is given by two mechanisms, on one of which the site is laid off, and on the other, the range.

Aiming point (P) is the object on which the panoramic sight of G is directed. (Figs. 4 and 5.)

Deflection (D) is the angle PGT measured counterclockwise (or the angle TGP measured clockwise) as set off on the panoramic sight. (Figs. 4 and 5.)

Deflection Difference (DD) is the difference in deflection applied to other than the directing gun of the battery necessary to bring it to bear on the proper portion of the target. For parallel fire DD is the parallax of the aiming point. (Fig. 6.)

Distribution is the lateral relation of the shots of a salvo.

After the definitions necessary have been well learned, there should be considerable practice in the use of mils. One important problem depends on nothing else, two others only on the use of mils and the range table. The first of these is the determination of the site from observations at the B. C. station (B). For this the formula (Fig. 2)

$$SI = 300 - \frac{LG - LT}{R}$$

may be used, where LG and LT are the levels of G and T above B, and R is one thousandth of the range. These levels are negative if G and T are below B, and this fact often leads to confusion. I think it better to not use any formula for this problem, rather to use a figure and to describe relative elevations as above or below. Such a problem is usually formulated as follows: $SI\ G$ at $B = 260$, $SI\ T$ at $B = 285$, $BG = 270$, $BT = 3000$, $Rn = 3100$. Find SI. We have $LT = -45$, T 45 below B, $LG = -11$, G 11 below B, T 34 below G, $si = \frac{-34}{3.1} = -11$, $SI = 289$.

The next of these problems is that of the clearance of a crest of known height and distance when firing on a target whose site and range are given. The clearance is given in mils by the formula

$$AD + si - \frac{c}{k} - ADC,$$

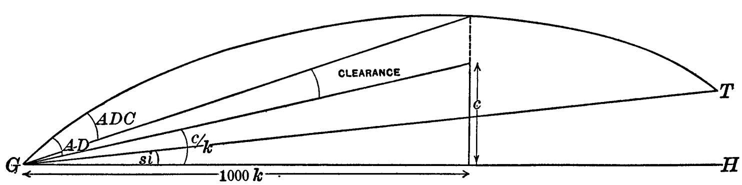

FIG. 3.

where c is the height of the crest in yards, 1,000 k the distance or range of the crest in yards, and ADC the angle of departure for the range of the crest. If

the value given by the formula is negative, the crest is not cleared. If we set the clearance equal to zero and solve for AD we have the angle of departure for the minimum range for the crest. The proof of this formula follows immediately from Fig. 3, provided that all angles involved are small enough to permit the use of the mil formula, as is usually the case in practice. An example of this kind requires evidently the use of a range table connecting AD and Rn (Danford and Moretti, page 254). Such a problem is usually formulated as follows:

Crest 20 yards high, 400 yards from battery; SI 295, Rn 2600. How much is crest cleared in mils and yards? What is minimum range for crest?

The clearance is $76 - 5 - 50 - 7 = 14$ mils, 5.6 yards.

AD for minimum range is 62, 2,250 yards.

The third problem is that of the proper location of the battery to the rear of a crest for a given target. It may be shown, if the tangent to the trajectory for the given target from a gun supposed on the crest is produced backwards to intersect the level ground to the rear of the crest, that a battery placed at the point of intersection will always clear the crest when firing on the given target. Such a problem is the following:

Crest is 15 yards above ground to the rear. Observer on crest finds for T, SI 290, Rn 3500. Where should guns be located? What is SI? How much is crest cleared?

Guns should be to rear of crest $1{,}000 \times \dfrac{15}{115 - 10} = 140$ yards. $SI = 300 - \dfrac{20}{3.64} = 294$. Clearance is $122 - 6 - 105 - 2 = 9$ mils, 1.3 yards.

These three kinds of problems are of considerable importance, furnish good practice in the use of mils, and give the student an opportunity to become familiar with the range table. I do not think that these problems should be once treated and practised and then laid aside, rather the student should be required to work at them occasionally throughout the whole course.

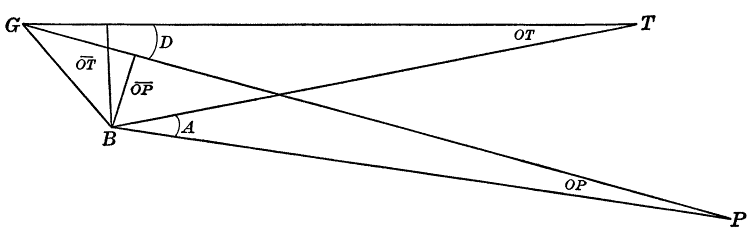

FIG. 4.

The most important of the problems of firing data is the calculation of the deflection for the directing gun, usually no. 2, as we count from the right when facing T. This problem should be introduced as early as possible and should be dwelt upon and hammered in until the students can do one in two minutes and until they consider it the easiest thing in the course. In Figs. 4 and 5, G is the directing gun, T the target, P the aiming point, B the B. C. station; the deflec-

tion D is the angle PGT measured counterclockwise, and is evidently greater or less than 3,200 mils according as P is to the left or right of GT; the angle PBT, which is called A, is measured at B; the angles at T and P, which in practice are small, are the *offsets* (offset angles) of target and aiming point respectively; the perpendiculars from B to GT and GP are also called offsets or offset distances. It is easily seen that

$$D = A \pm OT \pm OP,$$

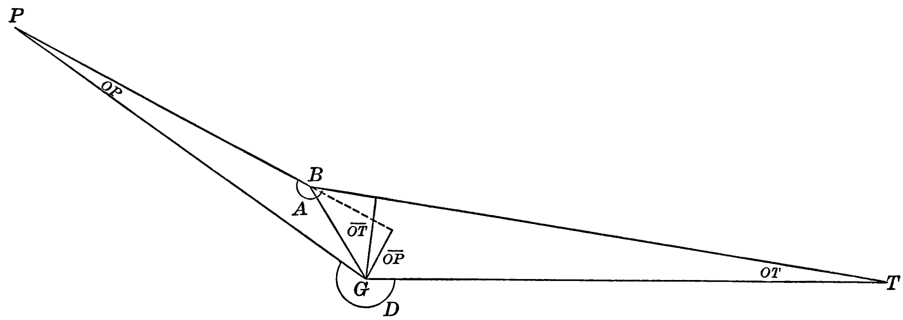

FIG. 5.

OT and OP denoting offset angles of target and aiming point respectively. The offset angles are found in mils from the offset distances,

$$OT = \frac{\overline{OT}}{\frac{1}{1000}BT} \qquad OP = \frac{\overline{OP}}{\frac{1}{1000}BP}.$$

It is clear that these formulas gain in accuracy by choosing B near G and P remote from B. In practice examples the distances BT, BP, $\overline{OT}$, $\overline{OP}$, are at first given. The range GT differs little from BT if B is near G, and may be taken as BT with a small correction, to be added or subtracted according as B is in front of or behind the line of guns, and given to the nearest hundred yards. The chief difficulty of the problem is in giving proper signs to the offset angles in the formula for D. These signs may be determined from a figure but this does not always eliminate the difficulty, as angles greater than a straight angle must frequently be used. I have used the following rules and believe they save time and make for accuracy:

1. B to left of GT, $+ OT$; right, $- OT$.
2. P behind BG, OP same sign as OT; front, opposite sign.

If in Fig. 4, we suppose $BT = 3{,}600$; $BP = 4{,}800$, $BG = 240$, $\overline{OT} = 200$, $\overline{OP} = 160$, $A = 710$, we have $OT = 56$, $OP = 33$, $D = A - OT + OP = 690$ (687), deflection being given to the nearest ten. $Rn = 3{,}700$.

In field practice, of which I shall say more later, the distances BT and BP are measured with a range finder, or may be taken from a map, or in case of necessity, estimated, *not guessed;* BG may be measured or estimated, or computed as follows: the gunner lays off 10 or 20 yards at G in a line perpendicular to BG, the angle subtended is measured at B, and BG is then computed from the mil

formula. But it is not easy to measure or to estimate accurately the offsets OT and OP. For this reason the method is modified (Fig. 5) by drawing the offset lines from G perpendicular to BT and BP; the offsets are then found from $\overline{OT} = BG \sin GBT$, $\overline{OP} = BG \sin PBG$; the range may if necessary be computed more accurately from $Rn = BT - BG \cos GBT$. This method requires the measurement of *two* angles at B. I think it is not desirable in this work to use the trigonometric functions of any but acute angles. The sign of the correction to BT for range can be seen at once, and is negative or positive according as B is to the rear or in front of the guns. The trigonometric work need not be accurate to more than one per cent. A trigonometric table of sines and cosines giving these functions to two decimals for every hundred mils is adequate, and may easily be written on a small card. It is most desirable and important that the student acquire great speed as well as accuracy in working deflection problems.

The deflection difference (DD) for parallel fire given to a battery with guns at equal normal intervals of 20 yards is that for gun no. 3 with no. 2 as directing gun. The DD for no. 4 is double that for no. 3, DD for no. 1 is that for no. 3 with the sign reversed. The DD given is positive or negative according as P is in front or to the rear of the line of guns, and is given to the nearest five mils. It is evident from Fig. 6, which is not drawn to scale, that in mils

$$DD = \frac{20 \cos D}{\frac{1}{1000} GP}$$

In practice average values of cos D, called obliquity factors, are used, each running for 400 mils. These factors are 1, .9, .7, .4, 0; the factor 1 runs from $D = 6{,}200$ through 6,400 to 200. The obliquity factors may conveniently be incorporated in the card trigonometric table whose use is suggested. The

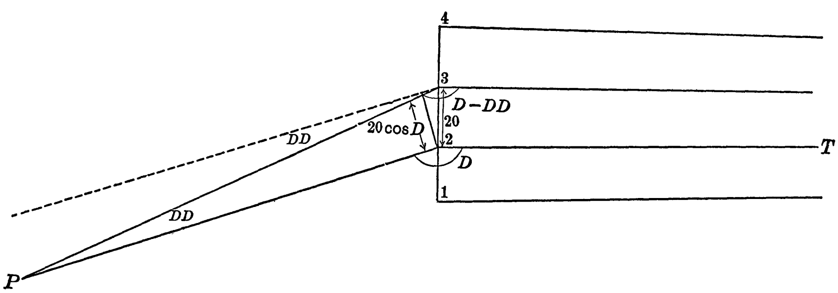

FIG. 6.

simplest method of computing DD is to write first the sign, second the obliquity factor, then $20/\frac{1}{1000} GP$, compute, and give result to the nearest five. In practice, since BP is known, and generally differs little from GP, BP may be used in place of GP. Suppose, for example, DD is required for parallel fire for battery at normal intervals; given GP 2,500 yards, D 2,300.

$$DD = -\ .7 \frac{20}{2.5} = -\ 5,\ (-\ 5.6).$$

An important type of problem, requiring only the use of the mil formula and the idea of *DD*, is the problem of distribution. Such problems are rather in "fire control" than in firing data, having to do with the correction of data from observation of the results of firing, but they have practical value and are of use to the student, and may well be considered in connection with the work in *DD*. They appear to be extremely confusing to the student, and for this reason I give in detail the solution of such a problem explaining what seems to me a good method of arranging the work. The following problem, slightly modified, is given in Danford and Moretti, no. 19, page 265:

Target is a battery at twice the normal interval, *Rn* 4,000. Battery is in position with intervals

.|. 24 .|. 8 .|. 16 .|.

A. P. is 2,500 yards distant, *D* is 2,300, and *DD* for parallel fire, guns at normal intervals, has been given to the guns. At the first salvo, the right gun is on its target. Give commands necessary to put the other guns on their proper targets. Draw diagram.

The diagram I draw as follows: The line of guns is represented on a vertical line at the left of the paper, the line of fire to the right across the paper, the target a vertical line on the right, *T* the point of impact of no. 2, the directing gun, the range written on the line of fire. The next step is to compute *DD* as given. This was found in a preceding paragraph to be -5. Determine next the point of impact of each gun with reference to *T*, points above *T* being represented by $T+$, below *T* by $T-$. We require for this the correct *DD* for parallel fire for each gun. These are respectively for nos. 3, 4, 1,

$$-7\frac{8}{2.5}=-2, \qquad -.7\frac{32}{2.5}=-9, \qquad +.7\frac{16}{2.5}=+4,$$

each computed to the nearest mil. These *DD* if used would give respectively as points of impact $T+8$, $T+32$, $T-16$. The *DD* actually used are respectively -5, -10, $+5$. The differences between the correct *DD* for parallel fire and those used produce changes in yards at 4,000 yards of -12, -4, $+4$, so that actual impact on the line of the target are for 1, 2, 3, 4 respectively

$$T-16+4=T-12, \quad T, \quad T+8-12=T-4, \quad T+32-4=T+28.$$

No. 1 is on its proper target; the proper targets of the other guns are the opposite guns of the enemy battery at 40 yard intervals, and are therefore $T+28$, $T+68$, $T+108$. Guns 2, 3, 4 should then be turned to the left, or their points of impact on the line of *T* raised, by 28, 72, and 80 yards respectively, that is their deflections, for 4,000 yards, increased by 7, 18, and 20 mils respectively. The actual work is conveniently arranged in lines, one for each gun:

No. 3 $DD=-.7\frac{8}{2.5}=-2$ Impact $T+8-12=T-4$ should be $T+68$ left 18

No. 4	$= -.7\,\frac{32}{2.5} = -9$	$T+32-4 = T+28$	$T+108$	20
1	$= +.7\,\frac{16}{2.5} = +4$	$T-16+4 = T-12$		
2		T	$T+28$	7

The last problem to be considered is also a problem of fire control, the correction of the firing data from the observed effect of a number of shots by an elementary application of the theory of probability. The theory of probability here used has no direct connection with the subject of probability as taught in "college algebra," but is based on the law of errors. Problems dealing with range, deflection, and height of burst are solved in the same way. I shall illustrate the method by solving a problem in the correction of range. The center of impact is a point in the line of fire such that an equal number of shots fall short of it and over it. A zone is an interval on the line of fire of which the center of impact is the center; the sixty per cent. zone, for example, is the zone within which sixty per cent. of the shots fall. The probability factor for any zone is the ratio of the width of that zone to the width of the fifty per cent. zone. A table of probability factors, the same for range, deflection, and height of burst, is given in Danford and Moretti, page 223. The probable error is one half the width of the fifty per cent. zone, and is the distance from the center of impact as often exceeded as not by the points of impact of all shots fired. The probable error varies with the range. A table of probable errors in range, deflection, and height of burst, for ranges from 1,500 to 5,000 yards, is given on page 220 of the same book.

Suppose it is observed in firing 12 rounds (shots) at *Rn* 2,000 that 10 fall short, 2 over the target. What change in range should be made?

We reason as follows: $\frac{1}{6} = 16\frac{2}{3}\%$ of the shots fall over; then T is at the further edge of the $66\frac{2}{3}\%$ zone. For *Rn* 2,000 the probable error in range is 34 yards; the probability factor for the $66\frac{2}{3}\%$ zone is 1.44. Then T is $1.44 \times 34 = 49$ yards beyond the center of impact. The range should be increased by 50 yards, no changes of range other than multiples of 25 yards being possible. Tables of probable errors and probability factors may be and should be dispensed with, for an officer of the Field Artillery should be as far as possible independent of tables. No considerable error will be made if the probable errors for all ranges in range, deflection, and height of burst are taken respectively as 30 yards, 2.4 mils, 1.8 mils. It may be a help to the memory to note that these figures are 5, 4, 3×6. These probable errors apply only to the U. S. 3″ gun. The probability factors for the 50%, 82%, 96% zones are respectively 1, 2, 3 nearly; these zones correspond to 25%, 25% + 16%, 25% + 16% + 7% respectively of shots beyond or short of the center. These figures are easily remembered if we note $2 + 5 = 1 + 6 = 7$. The probability factor required in any example is easily found with sufficient accuracy by interpolation. Thus if we work the example given above without consulting the printed tables

the probability factor is found for the $33\frac{1}{3}\%$ of shots between T and the center of impact as $1 + 8\frac{1}{3}/16 = 1.52$. The probable error being taken as 30 yards, the change to be made in range is again 50 (46) yards. While this work may seem very rough to the mathematician he may feel assured that it is of the greatest practical value.

I wish in the following pages to make certain general remarks concerning the course in firing data, which will, I hope, be of interest to any one planning such a course.

The only mathematical knowledge required of a student taking the course is arithmetic and a very little of each of the following, algebra, plane geometry, plane trigonometry. To do well in the course the student must learn to do accurately and quickly such multiplications and divisions as have appeared in the examples worked in the preceding pages. It is desirable that he should have a sense of accurate approximation, that he should learn to carry his arithmetical work far enough and not waste time by carrying it further. Speed in arithmetical work, as in every part of the work in computing firing data, should be a constant aim in the instruction. In algebra the student must be able to substitute numbers in such simple formulas as have appeared in this paper, to transform simple equations, and to handle negative signs without blundering. No geometry seems necessary beyond an appreciation of the equality of alternate-interior angles. In trigonometry it is necessary only to know how to find the legs of a right triangle, given the hypothenuse and one acute angle.

The time devoted to the course last year at Yale was three hours a week for half the college year. It was felt that this time was not enough for the students, mostly freshmen, to become thoroughly familiar with the problems of the course, and was certainly not enough for the students to learn to work these problems with proper speed. It was planned in the coming year to give to freshmen in the R. O. T. C. a three-hour course throughout the college year on trigonometry and firing data. Probably more than half the time in such a course would be given to firing data.

A very important part of the course is field work. It was not possible last year to give the students nearly enough practice outdoors. My division had five afternoons in the field and should have had at least twice as much. For outdoor work, "fire control" instruments, a range finder, and an aiming circle or scissors are very desirable, but probably cannot be obtained at present. If these instruments are not available the distances from the B. C. station to target and aiming point should be given to the students by the instructor or obtained by the students from a map, or may be estimated, if proper methods of estimation are taught. Such methods are given in Danford and Moretti, pages 146–149. Angles may be measured with some accuracy by a B. C. ruler, which is six inches long divided into sixty equal parts; to the center is attached a string twenty inches long. Each division of the ruler subtends an angle of five mils when the ruler is twenty inches from the eye, the whole ruler thus subtending 300 mils. Angles greater than a right angle should not be measured with a B. C. ruler; if

such an angle is required, a straight line should be run and the supplementary angle measured. To measure an angle of site it is necessary to establish a horizontal line. A simple and fairly satisfactory way to do so is the following: Construct accurately on a sketching board a line perpendicular to one edge and attach a string to a point of this line; in using, attach a weight to the other end of the string and move the board in a vertical plane until the string hangs along the line; the edge is then horizontal. Some distant object in a horizontal line with the observer, as nearly as possible in the same vertical plane with the observer and the point whose site is to be measured, may thus be determined, and the site measured with the B. C. ruler with an error probably not greater than five mils. Angles may be roughly measured by sighting over the knuckles of the clenched fist held at arm's length. Of course each observer must for this purpose know the scale of his own fist.

The course in firing data should if possible be coördinated with other courses, the outdoor work particularly with map making and panoramic sketching and with use of fire control instruments if these are available. For any part of the work, instruction in map reading and matériel (the mechanism of the gun) is useful. The course should be followed by a course in fire control, but the latter can probably be given satisfactorily only by a trained artillery officer.

The tables needed for the course have already been mentioned. They are range table, tables of probable errors and probability factors, and table of sines and cosines for angles in mils. All are given by Danford and Moretti. A brief but sufficiently accurate range table for the U. S. 3″ gun is here given. It seems however undesirable to lay emphasis on memorizing either the range table or the table of probable errors, since these apply only to the U. S. 3″ gun. In the following table the first column is range in yards, the second is the corresponding *AD*, the third, the change in *AD* for 100 yards' increase in range.

1000	20	3
2000	50	4
3000	90	5
4000	140	6
5000	200	7
6000	270	

					SIN	COS					
6400	3200		3200	0	0	1.00	1600	1600		4800	4800
6300	3300	1.	3100	100	0.10	0.99	1500	1700	0	4700	4900
6200	**3400**		**3000**	**200**	**0.20**	**0.98**	**1400**	**1800**		**4600**	**5000**
6100	3500		2900	300	0.29	0.96	1300	1900		4500	5100
6000	3600	.9	2800	400	0.38	0.92	1200	2000	.4	4400	5200
5900	**3700**		**2700**	**500**	**0.47**	**0.88**	**1100**	**2100**		**4300**	**5300**
5800	3800		2600	600	0.56	0.83	1000	2200		4200	5400
5700	3900	.7	2500	700	0.63	0.77	900	2300	.7	4100	5500
5600	4000		2400	800	0.71	0.71	800	2400		4000	5600
					COS	SIN					

In the trigonometric table above the sines and cosines for every hundred mils are given to two decimals. The obliquity factors for corresponding deflections are also given.

Of course it is necessary that the students work a large number of numerical problems. Danford and Moretti give a considerable number (pp. 263–282) taken from examinations held in the non-commissioned officers' course at the school of fire. The instructor will have no difficulty in making up any number of similar problems.

While there exists a large amount of literature on the subject of firing data, I believe that for an introductory course nothing further is necessary than the Drill and Service Regulations for Field Artillery and some text such as that of Danford and Moretti.

Requests for further information concerning the course in training for service in the Field Artillery at Yale may be addressed to the Curriculum Committee, Artillery Hall, New Haven, Conn.

YALE UNIVERSITY.
September, 1918.

COURSES IN NAVIGATION AT THE UNITED STATES NAVAL ACADEMY.[1]

The Department of Navigation at the Naval Academy gives two different courses, the regular course for midshipmen, and a special course for Reserve Officers. The two courses are similar in content, but differ greatly in method of presentation and in the amount of time allotted.

The course for midshipmen is preceded by a thorough course in spherical trigonometry and stereographic projections given by the Department of Mathematics. To this preliminary work about thirty-five recitations are devoted, approximately half of this time being given to the use of stereographic projections and to the logarithmic solution of the same problems treated by projection. The text book is Brown's Trigonometry and Stereographic Projections, published by the Naval Institute, Annapolis, and the tables used are Bowditch's "Useful Tables," from the text on navigation by this author.

The work under the Department of Navigation involves three recitations per week during the last three terms (semesters) of the academic course. In the spring term preceding the first class (senior) year, two months are devoted to a brief course in astronomy, based on White's Theoretical and Descriptive Astronomy (John Wiley and Sons), and the remainder of the term is given to such work in navigation as will best prepare the student for the practical work of the summer cruise. During the last year the whole field of navigation and compass deviations is covered with Muir's Navigation and Compass Deviations (Naval Institute, \$4.20) as a principal basis. Use is made of the Practical Manual of the Compass prepared at the Naval Academy (Naval Institute, \$1.75), also of Bowditch's American Practical Navigator, the Nautical Almanac, and Azimuth Tables, all publications of the Hydrographic Office, Navy Department, Washington, which may be purchased through the Superintendent of Public Documents.

The special course for Reserve Officers occupies sixteen weeks, five recitations

[1] We are indebted to Prof. R. E. Root for the informaton regarding these courses.

per week. In this course no use is made of stereographic projections, and for text books only the publications of the Hydrographic Office mentioned above are used. Each class is given six periods on board a naval vessel in practical instruction in the use of charts and instruments.

Following is an outline of the 16 weeks' course in Navigation for Reserve Officers as recently given.

1. The assignment of time was as follows:

16 weeks, 5 recitations per week (less 13 recitation periods devoted to written tests, holidays, etc.) .... 67 periods

Practical instruction on U. S. S. Dubuque .... 6 periods

2. During the first nine weeks of the course, the whole class covered the following ground:

(*a*) Geometrical and trigonometrical definitions and use of logarithm tables.
(*b*) Use of chip log, patent log, sounding machine, compass, azimuth, circle pelorus, binnacle, barometers, thermometers, and log book.
(*c*) Application of variation, deviation and compass error.
(*d*) Laying courses, plotting positions and bearings, and measuring distances on chart.
(*e*) Piloting, including cross bearings, two bearings and run between, sextant angles, and use of 3-arm protractor, soundings, lights, tides, etc.
(*f*) The sailings and dead reckoning.
(*g*) Use and adjustments of sextant.
(*h*) Comparison of chronometers, and error and rate of chronometers by noon "tick."
(*i*) Navigational and astronomical definitions.
(*j*) Use of Nautical Almanac.
(*k*) Conversion of arc to time, local to standard time, mean to apparent time, and finding G. M. T.
(*l*) Corrections to observed altitudes.
(*m*) Meridian altitude of sun and constant.
(*n*) Reduction to meridian (sun).
(*o*) Time sight of sun.
(*p*) Azimuth of sun and finding compass error.

3. At the end of eight weeks the class was divided on the basis of progress made; and during the 10th and 11th weeks, two separate courses were pursued:

1st, By the more backward students (about one third of the class), a review of (*c*), (*e*) and (*f*).

2d, By the more advanced students (about two thirds of the class).

(*q*) Conversion of solar to sidereal time.
(*r*) Conversion of sidereal to solar time.
(*s*) Meridian altitudes, reduction to meridian, and time sights of stars.
(*t*) Polaris sights.

4. During the 12th, 13th and 14th weeks, the whole class covered the following subjects:

(*u*) Finding compass error and use of Napier's diagram.
(*v*) Elementary practical compensation of the compass.
(*w*) Lines of position and chart intersections.
(*x*) Naval regulations and instructions on navigational subjects.

5. During the remainder of the time available, separate courses were again pursued by the two divisions of the class:

1st Division (advanced portion of the class).
(*y*) Method of St. Hilaire.
(*z*) Day's work.

2d Division (backward portion of the class).
(*q*), (*s*), (*t*) and (*y*).

6. All of the time assigned to Navigation on board the U. S. S. Dubuque was devoted to piloting, use of charts, use of compass, sextant, etc., and much of the regular section room time was devoted to practical instruction in use of charts, noon "tick," chronometers, barometers, compass, pelorus, three-arm protractors, tide tables, deviascope, etc.

NOTES AND NEWS.

Edited by D. A. Rothrock, Indiana University, Bloomington, Indiana.

Dr. S. D. Zeldin of the College of Hawaii has been appointed professor of mathematics in Olivet College.

Professor M. E. Graber has been elected to the chair of mathematics in Heidelberg University, Tiffin, Ohio.

Professor C. A. Barnhart, formerly of Carthage College, has been appointed professor of mathematics in the University of New Mexico.

Dr. W. O. Mendenhall, professor of mathematics in Earlham College, has been elected to the presidency of Friends University, Wichita, Kansas.

Assistant professor C. W. Watkeys has been advanced to a professorship of mathematics in the University of Rochester.

Professor Arnold Dresden of the University of Wisconsin sailed for France in September for service in the Red Cross.

Dr. F. R. Morris has been appointed instructor in mathematics at the University of California.

Mr. H. Lyle Smith, instructor in mathematics at Princeton University for the past two years, is now in the office of Major F. R. Moulton of the Ordnance Department at Washington.